

Team Orca Final Design Report ME 2125

TEAM ORCA

Overhead

Rapid

Can

Assembler



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Abstract

This report presents the design of a hydraulic can punching mechanism developed to punch cans accurately and sort them based on the required final length. The system uses a hydraulic cylinder to deliver the required punching force, a guided punch and die arrangement to ensure stable and even force application, and a conveyor-based filtering section to separate cans by final height. The design emphasizes feasibility, repeatability, ease of maintenance, and safe assembly by using standard fasteners and removable components rather than heavily welded joints. The punched cans are automatically sorted using a two-bar filtering mechanism, which accepts cans of the target height and rejects oversized or undersized cans. Supporting calculations were completed for cylinder sizing, stroke speed, flow rate, hydraulic power, and force verification to show that the design is technically feasible.

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1. Introduction and Objectives

1.1 Introduction

Can manufacturing involves several forming and finishing stages that convert aluminum stock into a lightweight, uniform, and high-volume product. Typical stages include blanking, drawing, wall ironing, trimming, necking, and finishing. For a can processing operation to be effective, the final product must meet dimensional requirements while maintaining speed, consistency, and minimal defects.

In this project, the focus is on the punching and sorting stage. The system must use a hydraulic press-based mechanism to punch cans and produce a final product that meets the required dimensional constraints. Beyond simply punching the can, the design must also provide a practical way of checking whether the punched cans satisfy the required final size. As a result, the mechanism was designed not only to apply the required force, but also to guide the can during operation and automatically sort acceptable and rejected cans after punching.

1.2 Objectives

The main objective of our design is to develop a hydraulic can punching mechanism that can punch cans accurately and consistently to the required final dimensions while maintaining smooth and controlled operation. The system is designed to use a hydraulic press to deliver the necessary punching force, while a guided punch and die arrangement ensures that the force is evenly distributed to reduce defects such as wrinkling and improve the quality of the final product.

A second objective of the design is to make the system practical and efficient by including a simple length filtering mechanism that automatically separates acceptable cans from oversized or undersized ones after punching. In addition, the design aims to be easy to assemble, repair, and modify by making use of standard parts such as bolts, shafts, bearings, and removable components rather than relying only on permanent welded joints. Overall, the objective is to create a feasible, reliable, and manufacturable system that combines punching accuracy, quality control, and ease of maintenance in one complete design

2. Design Concept

2.1 Overall Design Description

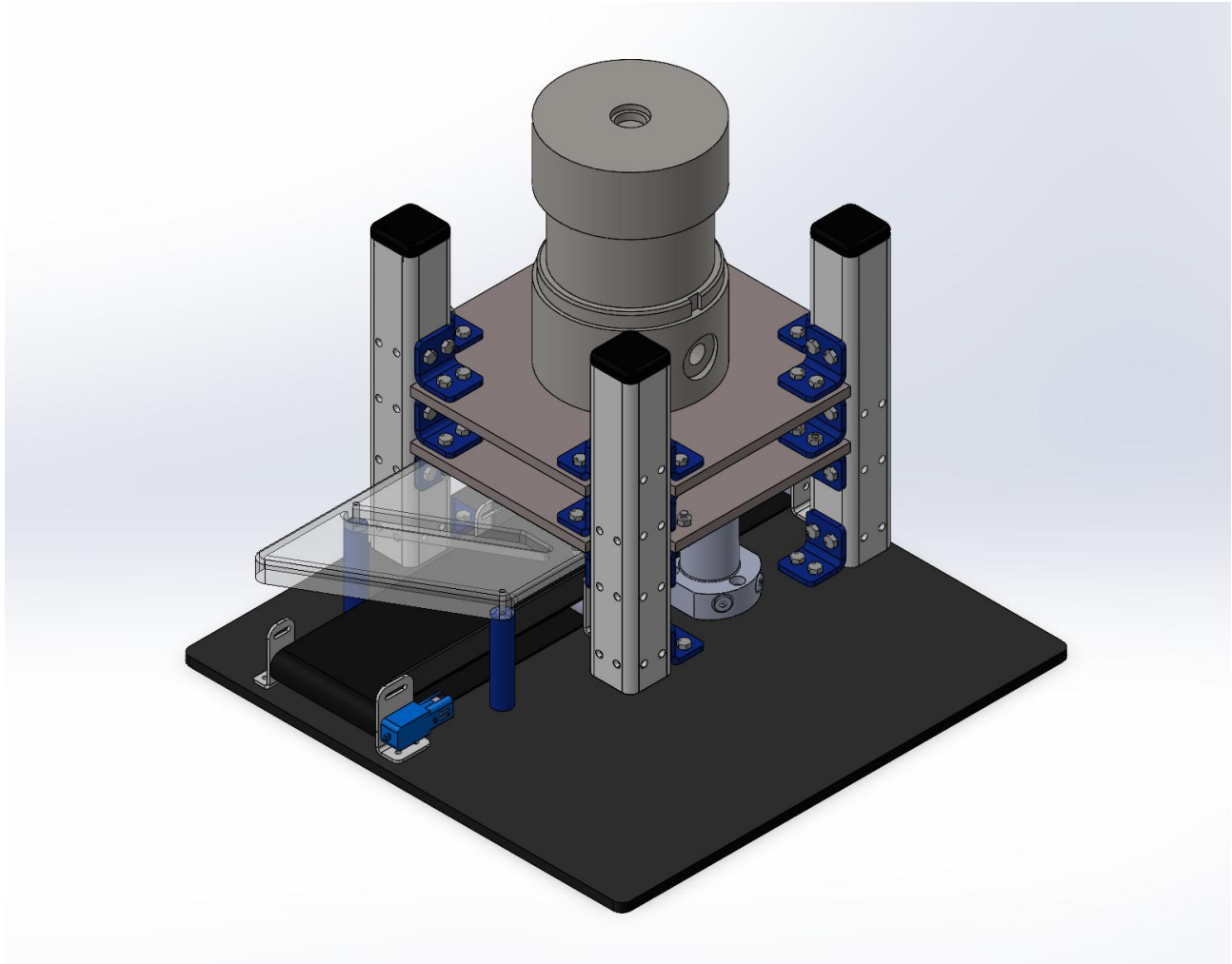


Figure 1: ORCA Assembly

The final design concept is a hydraulic press-based can punching and sorting mechanism as shown in Figure 1. The system is designed to punch cans accurately, efficiently, and consistently while also sorting the punched cans by their final height. The assembly consists of a hydraulic cylinder mounted at the top of the frame, a guide mechanism, a fixed die, angled spring holders, a discharge path onto a conveyor, and a two-bar length filtering system.

The hydraulic cylinder is the main working component of the design. It provides the vertical punching motion and the force required to cut or punch the can. Based on the provided calculations, the cylinder is designed for a required punch force of 185 kN at a system pressure of 25 MPa. The hydraulic system allows controlled motion, which is important because the punch must move straight downward into the can and then retract after the cut is complete.

A guide section is placed directly below the hydraulic cylinder. Its role is to ensure that the punch remains aligned during motion. By keeping the punch centered, the guide helps distribute the punching force more

evenly across the contact region. This improves consistency, supports repeatable operation, and helps prevent wrinkles in the can during punching.

The die is mounted securely in a slot below the guide. It acts as the receiving surface and cutting support during the punching process. The die must remain fixed in place during operation so that the punching action is accurate and repeatable. Because the die is a custom part that experiences direct contact loading, it is best manufactured by machining from a metal block or plate.

The punching section is designed around the can geometry. The can diameter used in the design is 6.6 cm, so the punch and surrounding support features are sized to fit this dimension properly. The accepted final punched can height is 5.5 cm, which is later used in the filtering stage. Designing the punching section around the Can dimensions ensures proper fit, stable positioning, and smoother operation.

The design includes angled spring holders to improve the motion of the can during and after punching. As the punch moves downward, the holders help guide and support the can. When the punch retracts upward, the angled holders help the punched can slide off instead of getting stuck under the punch. This feature reduces jamming and improves system flow without adding unnecessary complexity.

After punching, the can drops onto a conveyor system that moves it into the sorting section. The conveyor makes the system more practical because it allows the cans to be transported automatically between punching and filtering without requiring manual handling. The conveyor assembly uses a small motor, shafts, bearings, and a belt or conveying surface.

The filtering section uses two horizontal bars to sort cans by final height. The first horizontal bar is located at 5.6 cm and removes cans that are too tall. The second horizontal bar is positioned so that cans with the required final height of 5.5 cm are stopped and accepted. Cans shorter than the required value are not stopped and continue moving forward to be discarded. This gives the design a built-in quality control step.

A major strength of the design is that it relies mainly on standard fasteners and removable parts. This makes the design easier to assemble, repair, and modify than a heavily welded structure. Frame plates and brackets can be manufactured using cutting and drilling, while the die, guide, and punch support can be machined for better dimensional accuracy.

2.2 Main Mechanisms

Hydraulic Cylinder / Press: The hydraulic cylinder is the main working component of the design. It provides the vertical punching motion and the force required to cut or punch the can. Based on the provided calculations, the cylinder is designed for a required punch force of 185 kN at a system pressure of 25 MPa.

Guide Section: A guide section is placed directly below the hydraulic cylinder. Its role is to ensure that the punch remains aligned during motion. This improves punching quality and helps distribute force more evenly across the contact region.

Die: The die is mounted securely in a slot below the guide. It acts as the receiving surface and cutting support during the punching process. The die must remain fixed in place so that the punching action is accurate and repeatable.

Punching Cylinder Geometry: The punching section is designed around the can geometry. The can diameter used in the design is 6.6 cm, so the punch and surrounding support features are sized to fit this dimension properly. The accepted final punched can height is 5.5 cm, which is later used in the filtering stage.

Angled Spring Holders: The design includes angled spring holders to improve the motion of the can during and after punching. As the punch moves downward, the holders help guide and support the can. When the punch retracts upward, the angled holders help the punched can slide off instead of getting stuck under the punch.

Conveyor System: After punching, the can drops onto a conveyor system that moves it into the sorting section. The conveyor allows the cans to be transported automatically between punching and filtering without requiring manual handling.

Length Filtering Mechanism: The filtering section uses two horizontal bars to sort cans by final height. The first horizontal bar is located at 5.6 cm and removes cans that are too tall. The second horizontal bar is positioned so that cans with the required final height of 5.5 cm are stopped and accepted. Cans shorter than the required value are not stopped and continue moving forward to be discarded.

2.3 Manufacturing Considerations for Customized Parts

Each custom part was designed to easily be incorporated with commonly outsourced hardware.

Starting with the legs of the can former, 2x2 inch steel square tubing will be purchased, holes are to be drilled into the legs for the l brackets to screw into these holes would be best if drilled using either a standard mill or CNC mill or the pericon as they require a large amount of accuracy these screws would be threaded using a standard m7 thread it should be noted that lock tight will be used to compensate for vibrations. The height of the steel tube will need to be modified for this again a mill would be best as it allows for the best tolerances.

The L brackets used to mount the plates both mid top and bottom are to be made of sheet metal which will be pre cut using a plasma cutter then bent into the L shape using a press brake. The same process will be used for the conveyor l bracket also the dimension will be different.

The conveyer belt will have to be custom made material which can be pushed as sheets will be cut to the specified length then sown together.

both top mid and base plates will be CNC milled as high precision and accuracy are needed for the placement of the holes in particular the hole in the center of the plate needs to have an incredibly high tolerance as the can will be formed through this hole for the CNC milling was chosen for these parts. Since no holes need to be tapped a higher carbon steel was selected for here.

The x factor's sorting plate will be manufactured using high precision 3D printing as low tolerances typically that of 0.08 mm is acceptable for the sorting application.

All parts for the cylinder will be made on a CNC lathe. The custom hydraulic cylinders will be made using a CNC lathe for the high precision needed for hydraulics.

All stand off s and cylindrical parts will be made using a lathe.

To account for tolerances each part will be tested by a 3rd party company

3. Calculations

3.1 Given Data

- System pressure,
$$P = 25 \text{ MPa} = 25 \times 10^6 \text{ Pa}$$
- Required punch force,
$$F = 185 \text{ kN} = 185000 \text{ N}$$
- Stroke length,
$$L = 120 \text{ mm} = 0.12 \text{ m}$$
- Total cycle time
$$(\text{extend} + \text{retract}) = 0.50 \text{ s}$$
- Assumed equal extend and retract times:
$$t_e = 0.25 \text{ s}, t_r = 0.25 \text{ s}$$

These values define the operating conditions of the hydraulic punching system. They provide the pressure, force, stroke length, and cycle time needed to size the cylinder and estimate the speed, flow rate, and power requirements.

3.2 Governing Equations

- Pressure-force-area relationship:
$$F = P/A$$
- Bore diameter from area:
$$D = \sqrt{(4A/\pi)}$$
- Piston speed:
$$v = L/t$$
- Flow rate:
$$Q = A v$$
- Hydraulic power:
$$\text{Power} = P Q$$

These equations are standard hydraulic relations used to determine the cylinder size and system performance. They connect pressure, force, area, piston speed, flow rate, and hydraulic power, which are the key quantities needed to check if the design is feasible.

3.3 Required Piston Area

Using

$$A = F/P$$

the required bore-side piston area is

$$A = 185000 / (25 \times 10^6) = 0.0074 \text{ m}^2 = 74.0 \text{ cm}^2.$$

Therefore, the required extension-side piston area is

$$A_e = 0.007400 \text{ m}^2.$$

This calculation determines the piston area needed to generate the required 185 kN punch force at 25 MPa. The result makes sense because a larger force requirement at a fixed pressure always requires a larger piston area.

3.4 Equivalent Bore Diameter

Using

$$D = \sqrt{(4A/\pi)},$$

the equivalent cylinder bore diameter is

$$D = \sqrt{(4 \times 0.0074 / \pi)} = 0.0971 \text{ m} = 97.1 \text{ mm}.$$

The piston area is converted into a practical cylinder bore diameter so that a suitable hydraulic cylinder can be selected. The calculated diameter of 97.1 mm is reasonable for a high-force hydraulic punching application.

3.5 Retract-Side Effective Area

From the design data provided, the retract-side effective area is

$$A_r = 43.01 \text{ cm}^2 = 0.004301 \text{ m}^2.$$

This is smaller than the extension side because the piston rod reduces the available fluid area during retraction.

3.6 Piston Speed

Since each stroke is assumed to take 0.25 s, the piston speed is

$$v = L/t = 0.12 / 0.25 = 0.48 \text{ m/s}.$$

The piston speed shows how fast the cylinder must move to complete each stroke in 0.25 s. The value of 0.48 m/s is consistent with the required 0.50 s total cycle time and supports fast operation of the punching system.

3.7 Flow Rate Required

Extension flow rate:

Retraction flow rate:

The flow rate shows how much hydraulic fluid must be supplied to keep the piston moving at the required speed. The extension flow rate is higher than the retraction flow rate because the extension side has a larger effective area, so this result is physically reasonable.

3.8 Hydraulic Power Required

Extension power:

$$P_e = P Q_e = (25 \times 10^6)(0.003552) = 88.80 \text{ kW}.$$

Retraction power:

$$P_r = P Q_r = (25 \times 10^6)(0.002064) = 51.61 \text{ kW}.$$

The hydraulic power represents the power needed to supply both the required pressure and flow rate. The extension power is higher than the retraction power because the extension stroke requires the larger flow rate, making it the critical case for pump and motor selection.

3.9 Force Check

Extension/downstroke force:

$$F_e = P A_e = (25 \times 10^6)(0.007400) = 185.00 \text{ kN}.$$

Retraction force:

$$F_r = P A_r = (25 \times 10^6)(0.004301) = 107.53 \text{ kN}.$$

This step confirms that the selected cylinder dimensions can actually produce the required punching force. The extension force matches the design requirement, while the smaller retraction force is expected because the retract-side area is reduced by the piston rod.

3.10 Summary of Calculation Results

Table 1: Calculation Results Summary

Parameter	Value	Units
Equivalent bore diameter	97.1	mm
Extension/downstroke area	74.00	cm ²
Retract-side effective area	43.01	cm ²
Piston speed (each stroke)	0.48	m/s
Extension flow rate	213.12	L/min

Parameter	Value	Units
Retraction flow rate	123.87	L/min
Pump flow to size for	213.12	L/min
Extension hydraulic power	88.80	kW
Retraction hydraulic power	51.61	kW
Available extension force	185.00	kN
Available retraction force	107.53	kN

Overall, the calculations show that the hydraulic cylinder and supporting hydraulic system can meet the force and motion requirements of the design. The results are consistent and confirm that the proposed can punching mechanism is technically feasible.

3.11 Design Note

Achieving a full extend–retract cycle in 0.50 s requires a high pump flow rate of about 213.1 L/min and an ideal extension hydraulic power of about 88.8 kW. In practice, the actual motor power would be higher after accounting for volumetric, mechanical, and system losses.

4. Bill of Materials (BOM)

The following bill of materials is based on the available project information and the supplier references shown in the design notes.

Table 2: Bill Of Materials

Part Name	Quantity	Supplier	Approx. Price
Hydraulic Cylinder	1	Manufactured	\$500
Hydraulic Pump (PLSD 21, ~10,000 psi electric)	2	Enerpac	\$7,000 each
Hydraulic Gear Pump (6296K44)	1	McMaster-Carr	\$800
Medium-Strength Class 8.8 Steel Hex Head Screw	1 pack of 25	McMaster-Carr	\$15
Medium-Strength Class 8.8 Steel Hex Head Screw	2 packs of 10	McMaster-Carr	\$10 per pack

Part Name	Quantity	Supplier	Approx. Price
8-8 Stainless Steel Top-Lock Distorted-Thread Locknut	1 pack of 5	McMaster-Carr	\$12 per pack
8-8 Stainless Steel General Purpose Washer	1 pack of 100	McMaster-Carr	\$20
Linear Motion Shaft	2	McMaster-Carr	\$40 each
ServoCity 1/8" ID Flanged Ball Bearing	2	Amazon / Robot Shop	\$15 each
DC Gearbox Motor, "TT Motor," 200 RPM, 3 to 6 VDC	1	Adafruit	\$8
High-Elasticity Carbon Spring Steel Compression Springs	5	Amazon	\$10 total
Estimated Total Cost			\$15,500–\$16,000

5. Discussion of Feasibility and Viability

The proposed mechanism is both feasible and viable based on the design concept and calculations. From a feasibility standpoint, the design directly satisfies the main engineering requirements. It uses a hydraulic cylinder capable of delivering the required punch force, and the piston dimensions, pressure, and flow parameters were calculated to support that force. The guide and die arrangement provides stable and repeatable motion, while the punching geometry is designed around the can diameter and target final height.

From a viability standpoint, the design is practical to assemble and maintain. A major strength is the use of standard bolts, nuts, washers, shafts, bearings, and purchased components rather than relying only on permanent welded joints. This makes maintenance and future modifications easier. If a guide element, bracket, or spring holder wears out, it can be replaced without rebuilding the full structure.

The design is also improved by the addition of the conveyor and filtering system, which means the mechanism does more than simply punch cans. It also performs a basic quality control operation by sorting the cans according to final height. This increases the usefulness of the system and makes the design more complete.

A limitation of the current design is that the required hydraulic flow rate and power are relatively high for a very fast cycle time. This means the final implementation would need careful pump and motor selection. If this became a manufacturing constraint, one way to improve the design would be to slightly reduce the operating speed or optimize the stroke and hydraulic configuration to lower the flow demand.

Overall, the design is strong because it combines hydraulic force capability, guided punching accuracy, simple mechanical assembly, and automatic filtering in one integrated system.

6. Conclusion

The final design is a hydraulic can punching and length filtering mechanism capable of punching cans and automatically separating them based on final height. The design includes a hydraulic cylinder, guide section, fixed die, angled spring holders, conveyor, and filtering bars. Supporting calculations show that the cylinder can generate the required force and that the hydraulic system can deliver the necessary motion, flow rate, and power.

The mechanism is considered feasible because it satisfies the main force and dimensional requirements. It is considered viable because it uses practical components, allows easier maintenance through bolted assembly, and includes a built-in filtering stage for product checking. As a result, the final design represents a realistic and functional can punching solution.

7. Appendix

Appendix A – Assembly Drawing

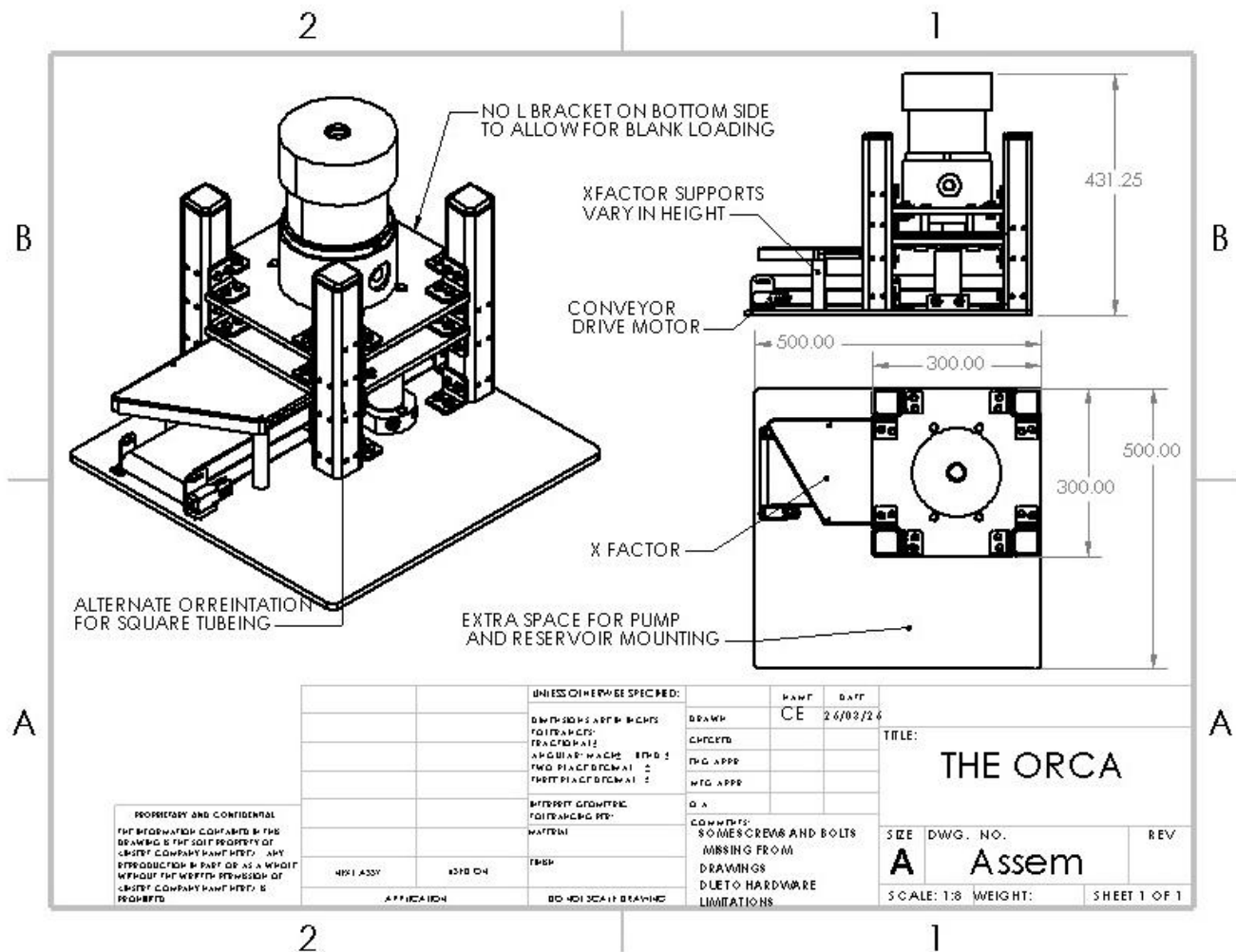


Figure 2: ORCA Assembly Drawing

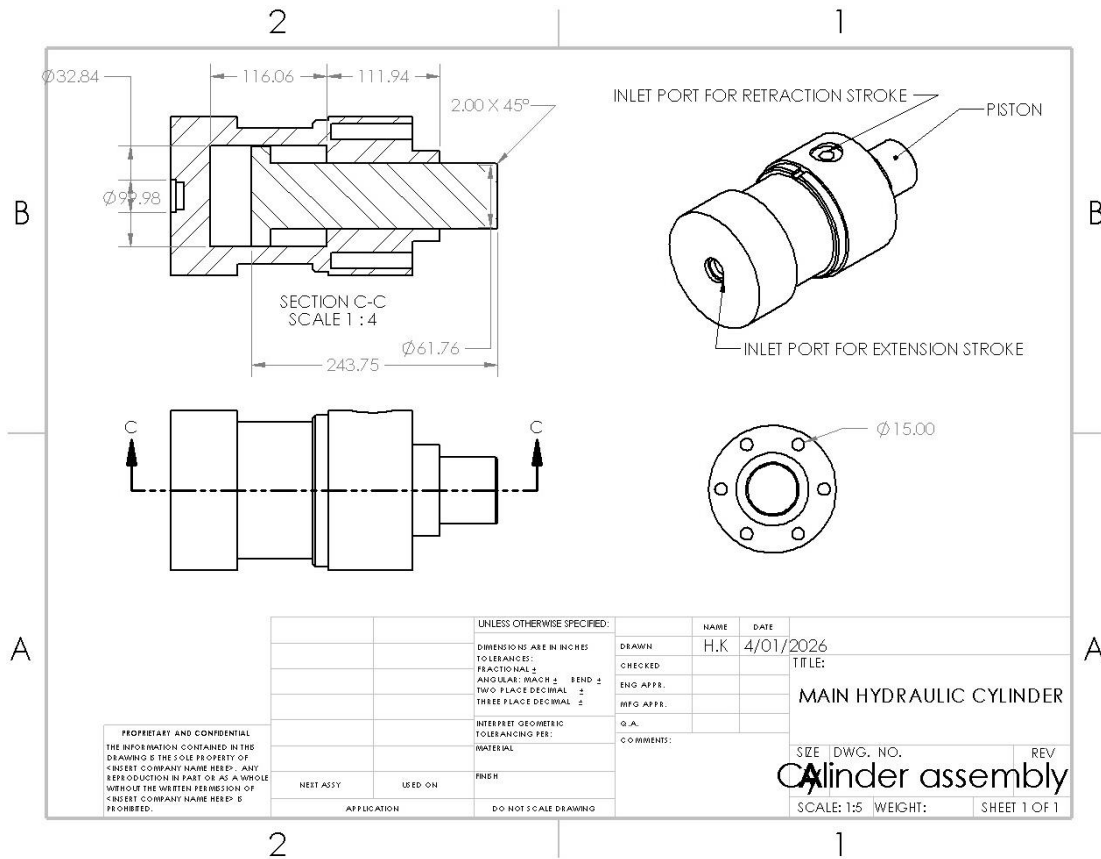


Figure 3: Hydraulic Cylinder Assembly Drawing

Appendix B – Individual Part Drawings

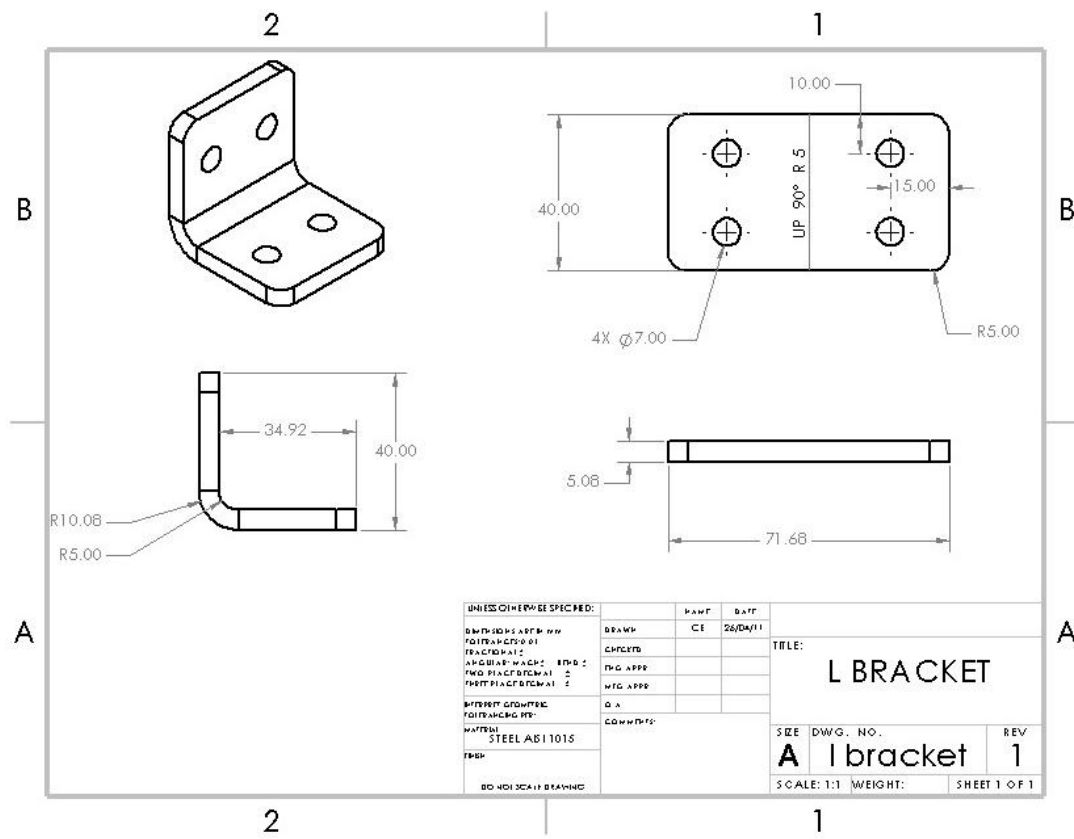


Figure 4: L Bracket Drawing

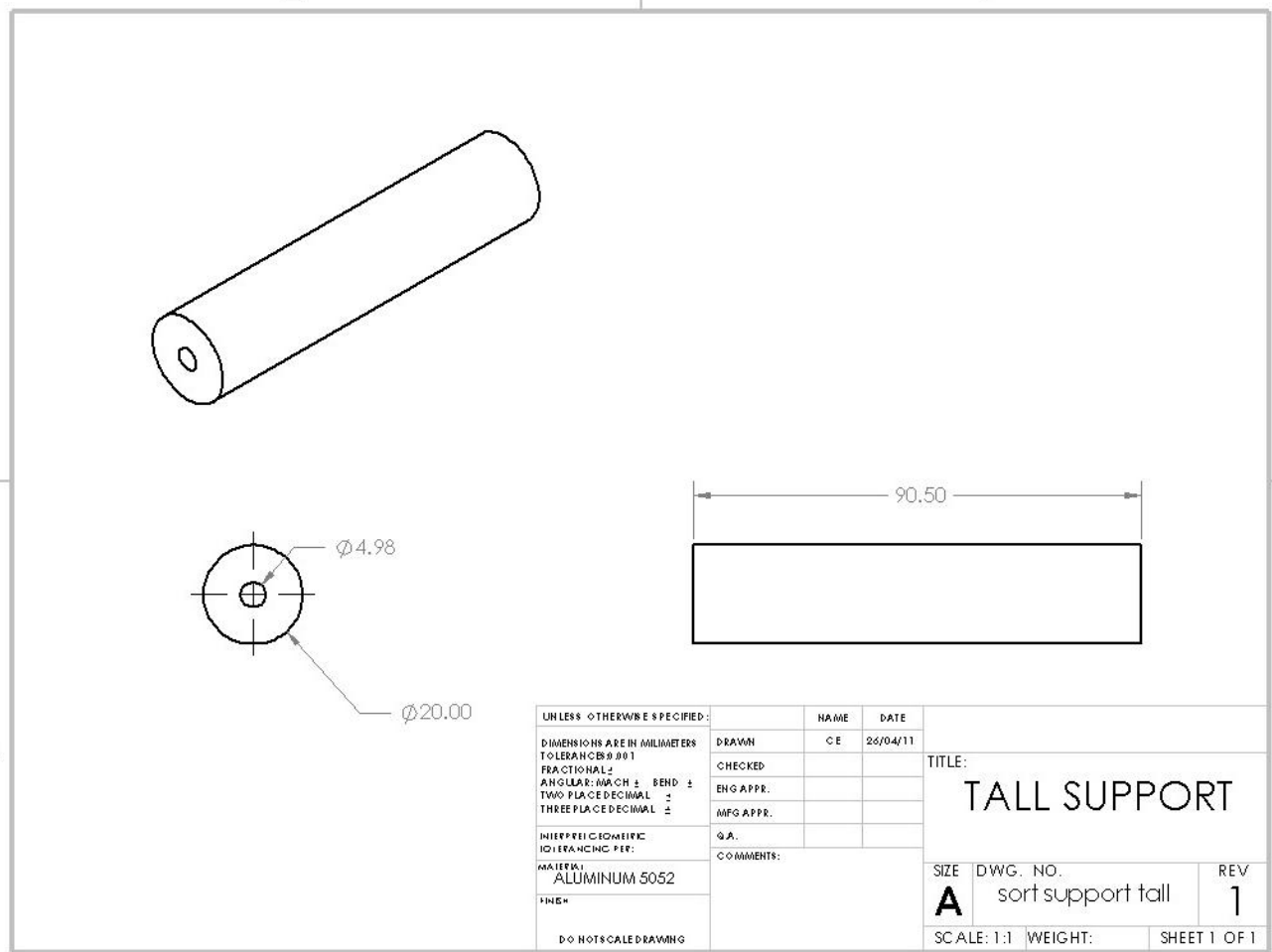


Figure 5: Tall Support Drawing

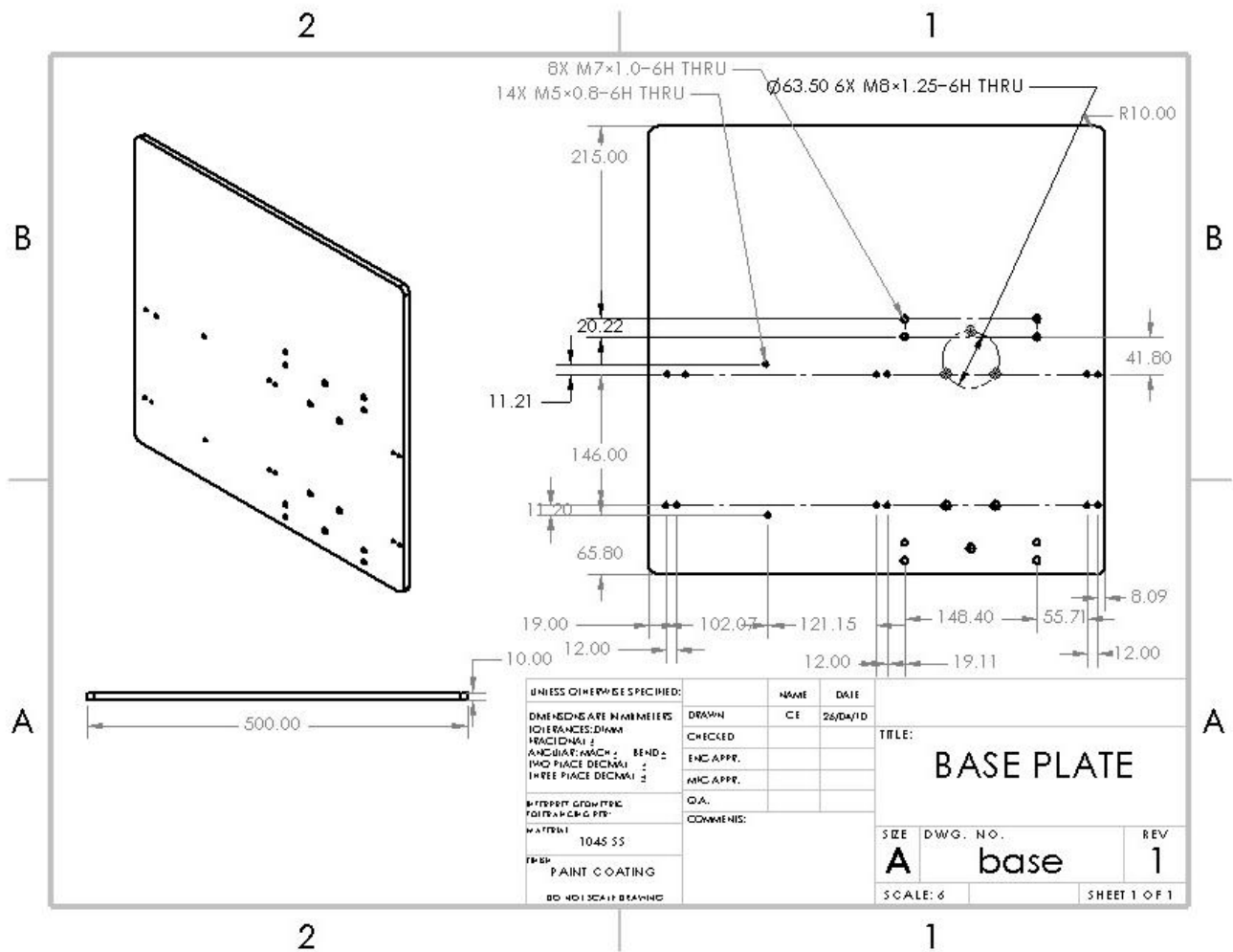


Figure 6: Base Plate Drawing

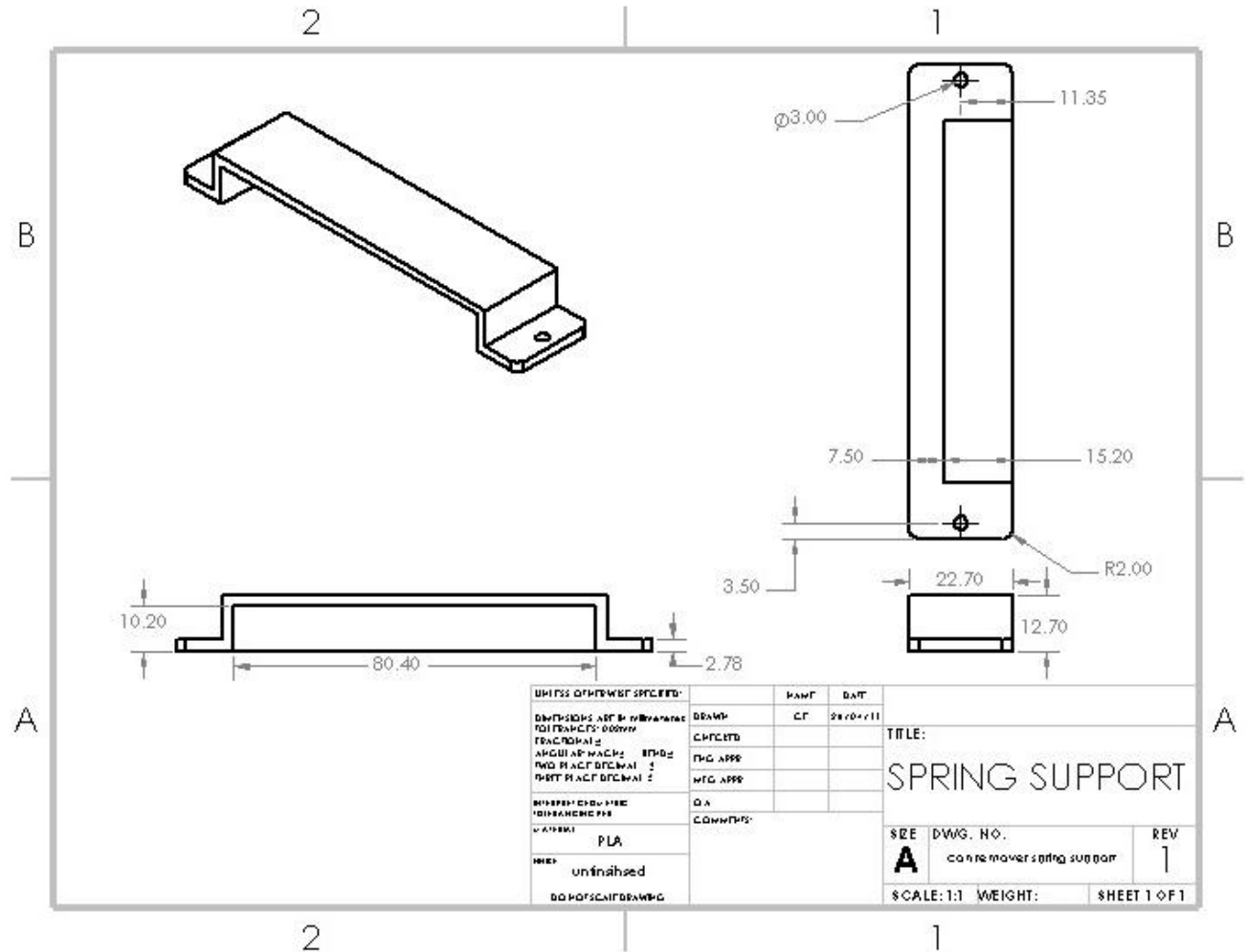


Figure 8: Spring Support Drawing

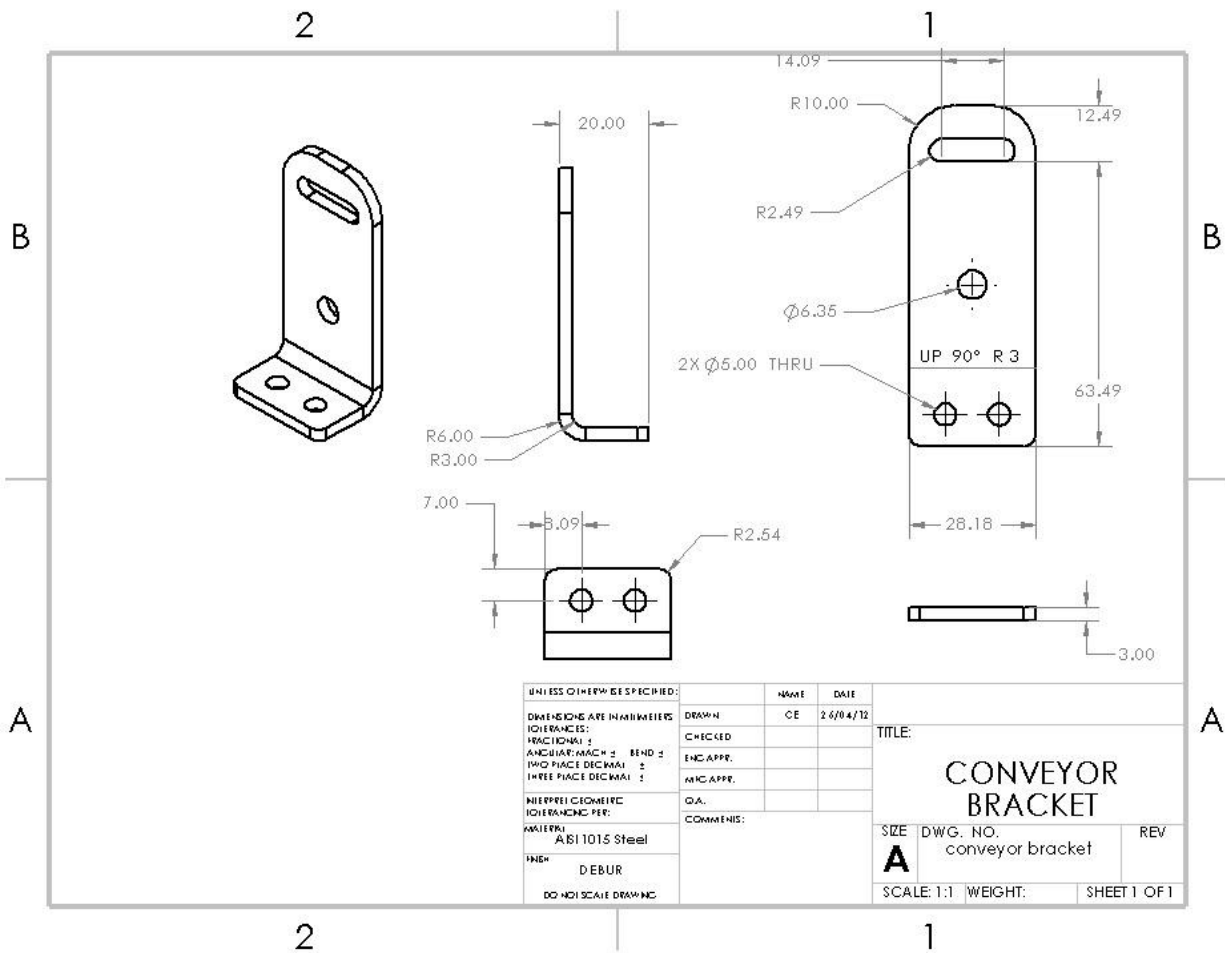
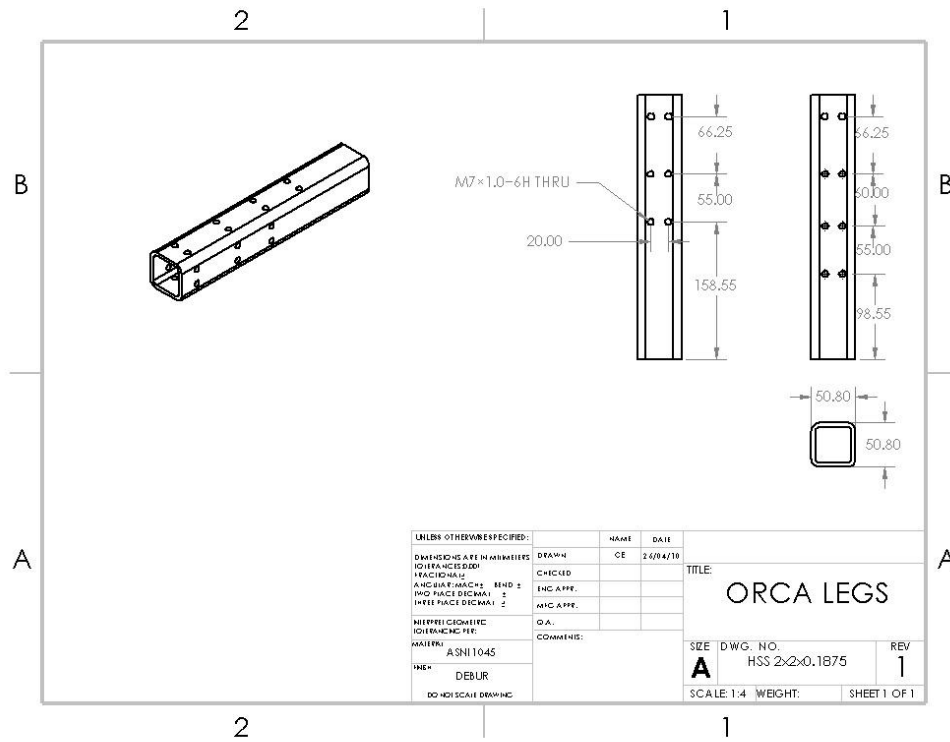


Figure 10: Conveyor Bracket Drawing



Appendix C – Supplier Datasheets.

The following supplier datasheets and product specification sheets are included for the off the shelf components selected for this design. These datasheets were chosen because they match the functional requirements of the can punching mechanism and represent realistic parts that could be ordered for fabrication of the system. Custom manufactured parts such as the die, frame, guide plate, filter bars, and support brackets do not require supplier datasheets and are instead represented by engineering drawings.

C.1 Electric Hydraulic Pump

Selected supplier: Enerpac

Representative product: ZE6 Series Electric Hydraulic Pump

Reason for selection: The Enerpac ZE6 electric pump family is suitable for high pressure hydraulic applications and includes models rated to 10,000 psi, which aligns with the pressure range used in the design calculations.

C.2 Linear Motion Shaft

Selected supplier: McMaster-Carr

Representative product: Linear Motion Shaft

Reason for selection: McMaster-Carr linear motion shafts are designed to work with linear bearings and shaft supports to provide smooth, precise motion, making them appropriate for guiding the punch assembly.

C.3 Flanged Ball Bearing

Selected supplier: ServoCity

Representative product: 1/8 in ID Flanged Ball Bearing

Reason for selection: ServoCity lists a 1/8 inch inner diameter flanged ball bearing with downloadable CAD resources, which makes it suitable for the conveyor or guided rotating support features in the mechanism.

C.4 DC Gearbox Motor

Selected supplier: Adafruit

Representative product: TT DC Gearbox Motor, 200 RPM, 3 to 6 VDC

Reason for selection: Adafruit lists a TT DC gearbox motor rated at 200 RPM and 3 to 6 VDC, which matches the motor description used in the bill of materials for the conveyor drive.

C.5 Compression Springs

Selected supplier: Commercial supplier such as Amazon

Representative product: High elasticity compression spring set

Reason for selection: Compression springs are required for the angled spring holder mechanism that helps guide the can during punching and assists release during retraction. The final purchased spring should be selected to match the required spring dimensions and stiffness used in the CAD assembly.

C.6 Hydraulic Gear Pump

Selected supplier: McMaster-Carr

Representative product: Rotary gear pump selection

Reason for selection: McMaster-Carr provides rotary gear pump product options and specification pages that can be used to select a pump matching the required hydraulic flow conditions of the system.

References

Adafruit. (n.d.). *DC gearbox motor - "TT motor" - 200 RPM - 3 to 6VDC*. Adafruit.

Enerpac. (n.d.). *ZE6 series electric pumps*. Enerpac. Retrieved April 12, 2026, from

McMaster-Carr. (n.d.). *Compression springs*. McMaster-Carr.

McMaster-Carr. (n.d.). *Linear motion shafts*. McMaster-Carr.

McMaster-Carr. (n.d.). *Rotary gear pumps*. McMaster-Carr.

ServoCity. (n.d.). *1/8" ID flanged ball bearing (1/4" OD, 7/64" thickness) - 2 pack*. ServoCity.

Libretexts. (2024, October 1). *12.1: Flow rate and its relation to velocity*. Physics LibreTexts.